# THERMAL IMAGING OF SKIN CHANGES ON THE FEET OF TYPE II DIABETICS

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*Abstract* – **Skin changes such as callosities and mycosis may be regarded as a risk factor for severe structural impairments including ulcers and osteomyelitis in patients suffering from diabetes. Increased temperature of the feet of diabetics is another frequent finding. We investigated the relationship between skin changes and areas of increased skin temperature recorded with an Infrared Scanner AGEMA 870. 76 patients who had type 2 diabetes longer than 5 years, were studied. A physical examination of their feet and nerve conduction tests were performed. Thermal images were taken from both legs in the anterior view, the foot from an anterior view and the soles.**

**230 sites of high temperature (hot spots) were detected on the thermal images of 75 soles. Toe deformities or deformity of the anterior foot arch, skin callosities, onychomycosis were not related to hot spots on the sole.**

**We confirm that about half of type II diabetes patients present with increased temperatures of their feet. However, no relationship with skin changes and areas of elevated skin temperature could be established. Thermal imaging does not identify the common skin changes found in the feet of diabetics.**

## I. INTRODUCTION

An increase of the skin temperature of feet was repeatedly reported in patients with diabetes [1-4}. Ring described normal values for the temperature gradients from the knee to the toes [5]. In the case of hot feet this gradient will be inverted with the forefoot on the same temperature level as the knee or above the knee temperature. Autonomic neuropathy [1,2}, increased local pressure due to poor footwear {3} and osteomyelitis [4] have been discussed as the reason for this phenomenon. The contribution of autonomic neuropathy is supported by reduced or absent responses of skin temperatures to thermal stimuli [6,7].

The presence of plantar callus is highly predictive of subsequent foot ulceration in diabetics who also suffer from neuropathy [8}. Removal of calluses results in lower local pressure [9]. Elevated skin temperatures at recognized sites of weight bearing (metatarsal heads and heels) are common in the diabetic neuropathic foot and may indicate tissue injury or inflammation induced by pressure trauma [2].

The risk odds ratio for diabetic subjects to have toenail onychomycosis was 2.77 times compared with normal individuals in a survey conducted in Canada [10]. Most onychomycoses are secondary to a mycosis of the adjacent skin [11], which may lead to increased temperatures caused by inflammation.

The objective of our study was to investigate the occurrence of inverted thermal gradients in type II diabetics and to correlate hot spots on their feet with callus formation, toe nail onychomycosis and foot arch and toe deformities.

## II. METHODOLOGY

76 patients who had type 2 diabetes longer than 5 years and HbA1c level > 7,5%, were investigated. A physical examination of their feet was performed including the measurement of range of motion of the ankle joint, recording the alignment of the feet at the subtalar joints, foot arches and toe deformities. Skin changes such as callus formation, toe nail onychomycosis and the occurrence of varicose veins were registered. The neurological examination comprised of sensory tests, tendon jerks and measurement of the nerve conduction velocity for both peroneal and sural nerves.

Thermal imaging was performed after the patients have acclimatised to a room temperature of 24°C for 20 minutes with undressed legs. Thermal images were taken at a fixed camera/object distance from both legs in the anterior view, the foot from a top view and the soles using a NEC Thermotracer. Regions of interest were defined over both knees, both forefeet and both soles. Hot spots were defined as any area at least 0.5° warmer than the surroundings. The thermal gradient was determined by subtraction of the temperature readings of the knee from the forefoot temperature. The cut-off point for a normal gradient was set at ≤ -1.0 ° K.

Single Measure Intraclass Correlation was calculated for hot spots on the plantar feet and anterior foot arch deformities, toe deformities, callus formation and onychomycosis respectively. Mann-/Whitney Test was used for comparison of findings in patients with normal and pathological temperature gradients. All calculations were performed with SPSS 10.0 for Windows.

## III. RESULTS

Mean age: of 76 investigated patients (47 female / 29 male) was 67 ± 10 years. They had suffered an average of 16 ± 9 years from diabetes. 42 patients were insulin dependent diabetics with mean values for HbA1c: 8,7 ± 1% and 163 ± 47 mg/dL for blood glucose. A pathological temperature gradient of the lower leg was found in 36 patients on the right leg (mean of pathological gradient: -0.59 ± 0.70°K versus –1.96 ± 0.62°K) in 39 patients on the left leg (-0.62 ± 0.9°K versus –2.13 ± 0,12 °K). The temperature readings of the sole (pathological gradient right side: 31.9 ± 1.1 versus 30.1 ± 1.0; pathological gradient left side: 32.1 ±

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**Abstract**

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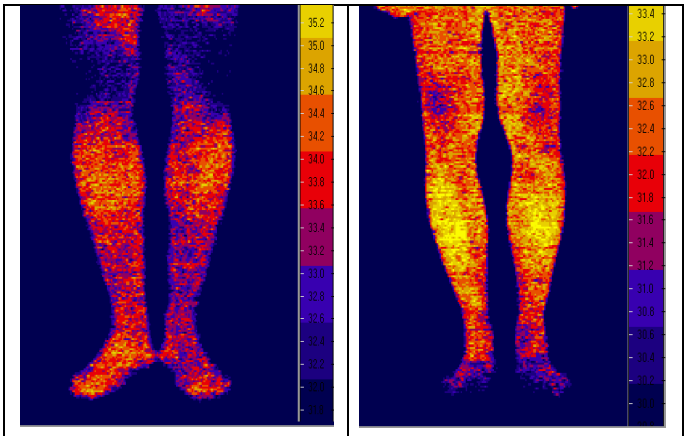
1.1 versus 30.1 ± 1.1) and the forefoot differed between patients with a normal and a pathological temperature gradient from the knee to the toes significantly.

Fig. 1 shows thermal images of typical pathological temperature gradients on the left hand side compared with normal temperature thermal gradients of the lower leg on the right hand side. The temperature of the feet on the left hand side of the image are about 2 ° above the knee temperatures.

FIGURE 1



Pathological gradient | Normal gradient

Callus formation was a common finding. Only 13 subjects did not show any callosities on their feet. 26 subjects presented with 1 to 3 callus formations, 16 patients showed 3 to-5 skin changes and 21 subjects showed more than 5 callosities.

26 patients presented with at least 1 toe nail affected by onychmycosis, 6 subjects had involvement of all toes. Table I shows the correlation between hot spots callosities, onychmycosis, toe deformities and changes of the anterior foot arch. No significant correlation between hot spots and any of the mentioned parameters could be detected.

Correlations between pathological temperature gradients, sensory loss,. pathological results of nerve conduction tests or the most recent concentration of HbA1c lacked also significance. A very week correlation was detected between normal temperature gradient and lack of clinical signs for varicose veins.

## IV. DISCUSSION

Although it is thought, that callus formation on the feet is the result of localized increase of pressure, we could not establish a relationship between callosities and hot spots on the thermograms of patients suffering from type II diabetes. The "Seattle Diabetic Foot Study"[12] had observed that hammer or claw toe deformity was associated with higher ulcer risk in certain subgroups. If this is true, this risk might not combined with temperature phenomena, because at least in our sample a correlation with toe deformities and hot spots was not found. However, areas of increased temperature are accepted as being predictive for the development of foot ulcers {2,3,4].

TABLE I

| | Single Measure Intraclass Correlation (95 % confidence interval) | | | |
|---|---|---|---|---|
| | callus | mycosis | Toe deformity | Arch deformity |
| Hot spot 1st right toe | 0.23 (0.00 to 0.43) | 0.02 (-0.20 to 0.24) | -0.07 (-0.29 to 0.16) | -0.12 (-0.34 to 0.11) |
| Hot spot 2nd right toe | 0.16 (-0.07 to 0.37) | 0.01 (-0.20 to 0.28) | 0.20 -0.03 to 0.40) | 0.01 (-0.21 to 0.23) |
| Hot spot 3rd right toe | -0.11 (-0.33 to 0.12) | 0.09 (-0.15 to 0.31) | 0.03 (-0.20 to 0.26) | 0.00 (-0.18 to 0.19) |
| Hot spot 4th right toe | -0.22 (-0.42 to 0.01) | 0.02 (-0.21 to 0.24) | -0.02 (-0.24 to 0.21) | -0.14 (-0.33 to 0.07) |
| Hot spot 5th right toe | -0.16 (-0.37 to 0.08) | -0.03 (-0.26 to 0.20) | -0.02 (-0.24 to 0.21) | -0.02 (-0.19 to 0.16) |
| Hot spot 1st left toe | -0.06 (-0.27 to 0.17) | -0.04 (-0.27 to 0.19) | 0.12 (-0.09 to 0.32) | 0.02 (-0.18 to 0.23) |
| Hot spot 2nd left toe | 0.09 (-0.12 to 0.30) | 0.13 (-0.09 to 0.35) | 0.25 (0.03 to 0.45) | 0.11 (-0.09 to 0.32) |
| Hot spot 3rd left toe | - 0.12 (-0.32 to 0.10) | 0.07 (-0.15 to 0.29) | 0.09 (-.014 to 0.31) | 0.07 (-0.13 to 0.28) |
| Hot spot 4th left toe | 0.25 (0.03 to 0.48) | -0.21 (-0.41 to0.01) | -0.15 (-0.37 to 0.07) | -0.03 (-0.21 to 0.17). |
| Hot spot 5th left toe | 0.04 (-0.19 to 0.26) | 0.01 (-0.21 to 0.24) | 0.02 (-0.21 to 0.24) | 0.00 (-0.17 to 0.19) |

## V. CONCLUSION

We could confirm that about half of type 2 diabetes patients present with a disturbed temperature gradient of the leg, but this increase of temperature of the feet is not related with common skin changes such as callosities or onychomycosis. Thermal imaging cannot usefully identify the common skin changes found in the feet of diabetics.

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